

Toward Seamless Weather-Climate Prediction with a Global Cloud Resolving Model

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LONG-TERM GOAL

The long-term goal of this project is to developing a seamless weather and climate prediction system that has capability to predict accurately both weather phenomena such as tropical cyclones (TC) and other extreme weather events and longer climate-scale phenomena such as the Madden-Julian Oscillation (MJO) and the El Nino-Southern Oscillation (ENSO). Organized moist convections in the tropical atmosphere have their origins at space scale of less than 10 km, and they play a key role in the initiation and maintenance of mesoscale weather events such as super cloud clusters and large-scale phenomena such as MJO. The Navy is in urgent need to develop such a global high resolution model that has a proper dynamic core and physics packages and is capable of representing realistically convection and clouds across a wide range of spatial and temporal scales and suitable for prediction of extreme events in regional and global scales.

OBJECTIVE

We aim to develop a new global model framework with the goal of reducing the uncertainty in moist convective processes. We propose to use the Geophysical Fluid Dynamics Laboratory (GFDL) High-Resolution Atmospheric Model (HiRAM) as a base framework for the next generation Navy global cloud resolving system. The HiRAM is based on a highly scalable finite volume dynamic core formulated on a cubed sphere. It is a non-hydrostatic, “cloud-resolving capable” global model designed to be applicable for a wide range of horizontal resolution from 100 km to 1 km. The objective of this

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project is to systematically evaluate the model's performance in weather (short and extended range) and climate (seasonal) predictions and provide a basis for the construction of next-generation Navy global cloud-resolving atmospheric forecast system suitable for operational requirements. We will in particular demonstrate the capability of this model in reproducing both short-range weather events such as mid-latitude synoptic systems and TCs and long-range climate variability such as MJO and ENSO teleconnection.

APPROACH

We plan to conduct the following three types of experiments using HiRAM, with various horizontal resolutions from 25 km to 12.5 km, depending on the length of the model integration.

Weather forecast experiment. The first experiment is daily 10-day forecasts at the 25-km for a continuous period of one years, starting from spring of 2012. The 12.5-km resolution can be done for shorter period (for example, at hurricane season) pending on the availability of computing resources at GFDL. This experiment is designed to evaluate the model performance in the conventional “weather forecast mode”. A systematic evaluation of the model short-range weather forecast capability will be conducted and results will be compared with current operational models such as the Navy NOGAPS/NAVGEN and NCEP GFS. A special attention will be to the forecast skill of TC track and intensity and winter mid-latitude synoptic-scale systems.

AMIP-type experiment. The second is an AMIP-type experiment. The model is run for 20 years (1990-2010) with monthly or weekly observed SST as a lower boundary condition. The inclusion of a longer period is needed in order to examine the model's performance in reproducing the atmospheric internal modes such as MJO and teleconnection patterns associated with El Nino. This experiment may be identified as a “free run mode”. Either a 25 km or a 12.5 km resolution will be used for the AMIP run. The capability of reproducing the observed MJO and ENSO variability in the “free run mode” is crucial for extended-range weather forecast. It has been shown that TC and other synoptic wave activity are to a large extent controlled by low-frequency oscillations such as MJO and ENSO (Liebermann et al. 1994, Sobel and Maloney 2000, Fu et al. 2007, Hsu and Li 2011). Only when a model can capture realistic MJO structure and evolution in a free run, can this model predict the growth, propagation and phase transition of a real-case MJO event (otherwise the initial MJO signals would damp quickly with time).

Seasonal prediction experiment. The third is a seasonal prediction experiment similar to our TC forecast experiment shown in Fig. 1. This may be termed as a “seasonal prediction mode”. Such type of experiment is one step further toward achieving the goal of seamless weather-climate forecast. Through the evaluation of the model's seasonal forecast skill with forecasted SST (in which SST is determined based on the climatologic annual cycle plus a SST anomaly frozen at forecast initialization date), we will examine the model's practical predictability in extended range weather and seasonal climate prediction. The model's systematic bias in reproducing the seasonal mean state will be first examined, followed by the bias analysis in seasonal anomalies. The signal to noise ratio will be examined through multi-ensemble experiments. In addition to examining seasonal TC forecast skills in various basins, we will also examine the forecast skills in regional climate systems including the Asian monsoon, mid-latitude storm track, and the Pacific-North America pattern. The seasonal forecast experiments will be carried out for each season, in order to reveal the seasonal dependence of the model forecast capability.

Once the aforementioned experiments are completed, we will further evaluate the model's performance and assess the model forecast skills in both short and long ranges. Conventional diagnostic methods adopted at current operational centers will be used to evaluate the model short-range weather forecast capability. Other diagnosis matrices such as the Wheeler-Hendon RMM based anomaly correlation coefficient (ACC) index and the signal-noise ratio based predictability index will be used to assess the model extended-range forecast skill. A box difference index (BDI) will be applied to evaluate the relationships between TC genesis and large-scale pattern in various basins (e.g., tropical North Atlantic, eastern North Pacific, and western North Pacific). Additionally we will evaluate the model's performance in reproducing the MJO variability and the ENSO teleconnection patterns.

WORK COMPLETED

The project was started 6 months ago. An oral presentation about the overall project objective and planned activity was given by the PI in the Monterey meeting in July 2012, organized by Dr. Ron Ferek. We are currently running both the HiRAM weather forecast experiment and AMIP-type experiment at GFDL supercomputers. It is anticipated that these experiments will be completed in a few months. Once completed, we will collect all HiRAM outputs and diagnose the simulation/forecast results.

RESULTS

Currently there are no significant results to be reported.

IMPACT/APPLICATIONS

N/A

TRANSITIONS

N/A

RELATED PROJECTS

This project is complementary to our NSF funding entitled “Upscale feedback of tropical atmospheric synoptic-scale variability to intra-seasonal oscillation” in which we are investigating two-way interactions between the synoptic-scale motion (including TC) and MJO.

PUBLICATIONS

No.